Shallow Ocean Bottom BRDF Prediction, Modeling, and Inversion via Simulation with Surface/Volume Data Derived from X-Ray Tomography

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LONG-TERM GOALS

We are investigating the measurable features in the BRDF (Bi-directional Reflectance Distribution Function) of benthic surfaces made of natural sediments and how that is influenced by the morphology of the sediment grain composition. If the measured BRDF shows features which can be numerically derived from the physical properties such as size and shape of the sediment material, then we should be able to invert BRDF data to obtain significant characterizations of the natural sediment properties.

OBJECTIVES

Extend current numerical BRDF ray tracing techniques to deal with natural sediments via input of sediment grain data from x-ray CT measurements. Discover if the BRDF data can be inverted to give information about grain size, morphology and interstitial spacing.

APPROACH

We are combining three areas of expertise, Ken Voss is measuring the BRDF of natural sediments, Allen Reed is aquiring detailed x-ray CT (computerized tomographic) data of natural sediments, and Chris Boynton is numerically deriving the BRDF via optical ray tracing of the sediment grain morphology (position, size, surface and orientation) obtained from the x-ray tomography data.

We are applying these three separate techniques to surfaces composed of three to four distinct natural sediment types, and one surface composed of spheres. We are using the spheres to understand and minimize the errors due to sub-resolution representation of the surfaces of the grains. Show in Figure 1 is an example of a natural sediment composed of mostly Carbonate Ooids.

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Figure 1. Carbonate Ooid sample sediment surface
[Image: a sample surface composed of Carbonate Ooids magnified to show the polished nature of the individual surfaces, the general ovoid shape and the general size distribution of the grains which appear to vary by no more than a factor of two in linear dimension.]

Ken Voss at the University of Miami Physics Department is using the previously developed BRDF meter capable of in-situ underwater and laboratory measurements [1] to measure the BRDF of the sample surfaces.

Allen Reed at NRL Stennis Space Center is aquiring the X-ray tomographic data from the prepared and optically measured sediments. The X-Ray tomographic technique produces data that gives a fine scale three dimensional description of the surface geometry of each individual grain and the interstitial spaces. Below are graphically rendered examples of the data from the X-ray CT device. Figure 2 shows a cubic section of the data revealing the detail of the grain and interstitial spacing. Figure 3 shows an individual grain's data extracted from the data represented in Figure 2 indicating the detail of the individual grains surface shape obtained from the x-ray CT data.

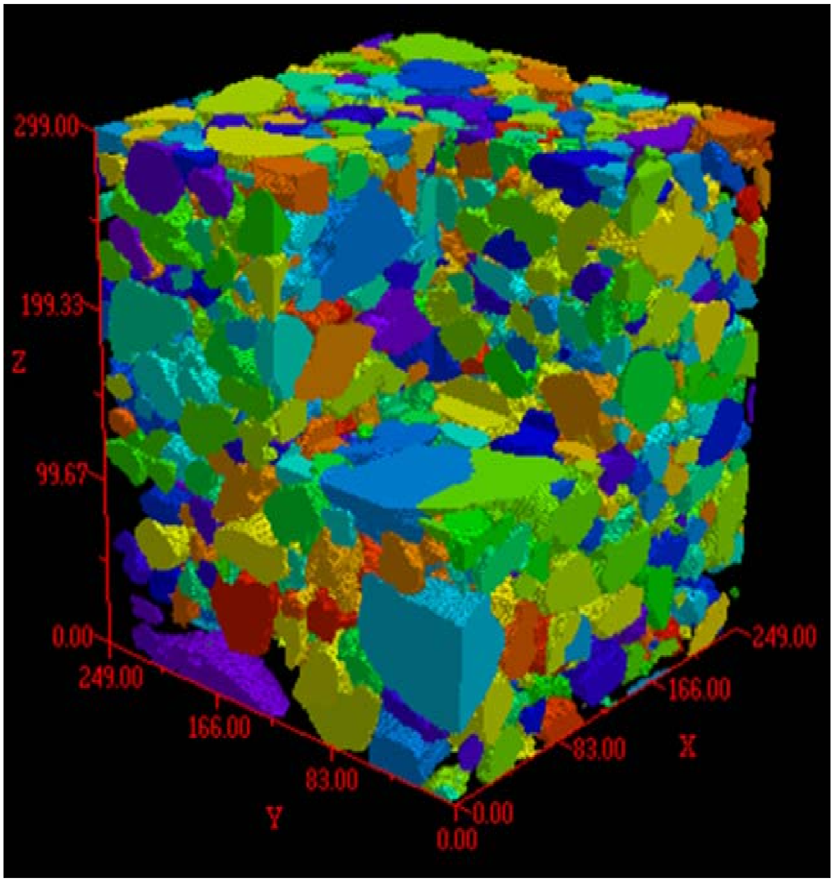

Figure 2. Example section of x-ray CT data provided by Allen Reed, NRL SSC.
[Image: three dimensional cubic section of natural sediment showing individual grains and interstitial spaces]

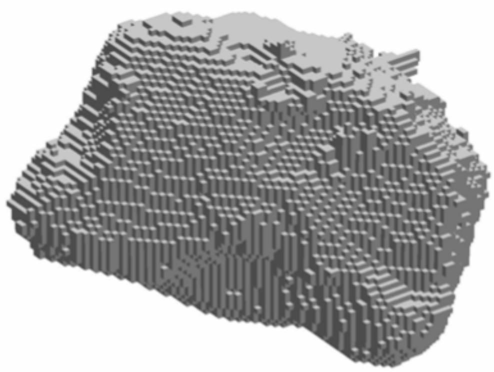

Figure 3. Example x-ray CT data of individual grain in Figure 2.
[Image: individual grain surface and apparent volume shown in a three dimensional representation]

Chris Boynton at the University of Miami Physics Department is doing the numerical ray tracing derivation of the BRDF using the grain data from the X-ray tomography measurements of the sediments. Below is an example of the numerically derived BRDF for surface composed of packed spheres.

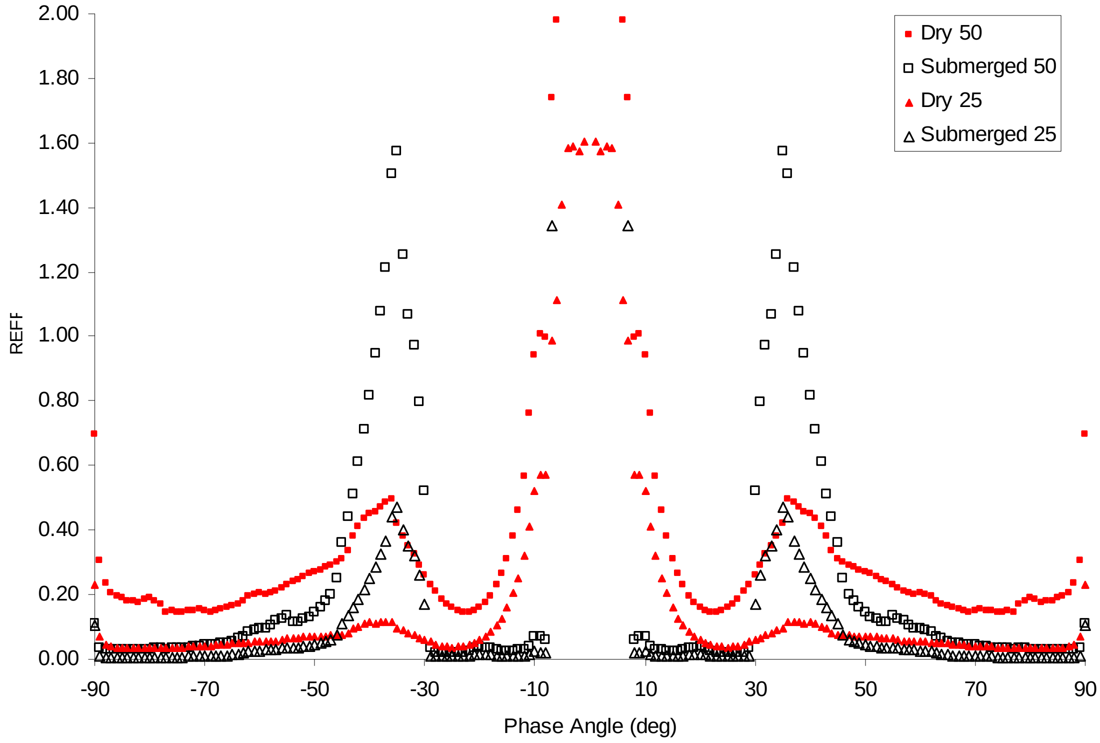

Figure 4. Calculated REFF (BRDF normalized to the BRDF of a 100% lambertian reflector) versus phase angle (0 deg phase angle, direct backscattering) for mixtures of lambertian and clear spheres in a regular close packed array when dry or submerged in water. Illumination is at 0 degrees. [Graph: illustrating fine detail in BRDF data available from numerical calculation and the darkening effect of submerging mixtures of clear and "gray" particles]

WORK COMPLETED

The numerical technique for deriving the BRDF has been extended to deal with random particle properties found in natural sediments. We have also manufactured sample holders that are compatible with obtaining measurements from both the BRDF meter and the x-ray CT device without disturbing the sample surface.

RESULTS

The improved numerical ray tracing technique for deriving the BRDF of surfaces composed of particles with non-symetric properties has been verified against the previous symetric technique. The technique works and we are now planning to test it against x-ray CT data for surfaces composed of spheres and then natural benthic sediments.

IMPACT/APPLICATIONS

If the BRDF is sufficiently sensitive to bulk sediment morphology, then it maybe invertible allowing for prediction of local sediment morphology via remote sensing.

RELATED PROJECTS

None.

REFERENCES

[1] Voss, K.J. et al, "Instrument to measure the Bidirectional reflectance distribution function of surfaces", Applied Optics **39,** 6197-6206 (2000)